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Abundance of resident Atlantic cod in Gilbert Bay, Labrador, based on mark recapture, sampling catch per unit effort and commercial tag return data collected from 1998 to 2002.

Abondance de la morue atlantique résidente dans la baie Gilbert, au Labrador, basée sur des données de marquage et recapture, de prises par unité d'effort et de retours d'étiquettes dans la pêche commerciale de 1998 à 2002.

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Abstract

Gilbert Bay is located along the southern coast of Labrador (52°35'N, 56°00'W) near the communities of Williams Harbour and Port Hope Simpson. It was designated as an Area of Interest (AOI) in the Marine Protected Areas (MPA) Program by the Department of Fisheries and Oceans (DFO), on October 12, 2000. Mark-recapture data from an arm of Gilbert Bay, catch per unit effort data from research sampling, and commercial tag return data were used to estimate the size of the resident cod population. Atlantic cod tagged and later recaptured during scientific sampling form the basis of the population estimate. Catch per unit effort from several locations in the bay indicates that cod are not uniformly distributed during the spring spawning period. Tags returned by commercial fishers indicate that the largest fish in the population are disproportionately caught by commercial fishers. The mark recapture data indicates that the Gilbert Bay cod population has a biomass of less than 70 tons. Commercial fishing mortality during 1998 and 1999 was estimated at 18 t and 16 t respectively, while recreational fishing mortality during 1998 was estimated at 1000 kg. If the biomass is about 70 t, the population can not sustain commercial fishing at 1998 and 1999 levels. More research is necessary to assess the assumptions on which our estimate is based. Management decisions concerning this stock should be made separately from northern cod and reflect the small and uncertain size of the population.

Résumé

La baie Gilbert est située le long de la côte sud du Labrador (52° 35'N et 56° 00'O) près des localités de Williams Harbour et de Port Hope Simpson. Elle a été désignée zone d'intérêt (ZI) dans le cadre du Programme de zones de protection marines (ZPM) par le ministère des Pêches et des Océans (MPO) le 12 octobre 2000. On a utilisé des données de marquage-recapture dans un bras de la baie Gilbert, des données sur les prises par unité d'effort provenant de l'échantillonnage scientifique et les données sur les retours d'étiquettes dans la pêche commerciale pour estimer l'effectif de la population de morue résidente. Cette estimation est fondée principalement sur les morues de l'Atlantique étiquetées et reprises ultérieurement lors d'un échantillonnage scientifique. Les prises par unité d'effort en plusieurs endroits de la baie révèlent que la morue n'est pas uniformément répartie durant la période de fraye printanière. D'après les étiquettes renvoyées par les pêcheurs commerciaux, les plus grands poissons de la population sont capturés de manière disproportionnée par ces pêcheurs. Les données de marquage-recapture révèlent que la biomasse de la population de morue de la baie Gilbert est inférieure à 70 tonnes. La mortalité par pêche commerciale en 1998 et 1999 a été estimée à 18 t et 16 t, respectivement, tandis que la mortalité par pêche récréative en 1998 a été estimée à 1 000 kg. Si la biomasse est d'environ 70 t, la population ne peut soutenir une pêche commerciale aux niveaux de 1998 et 1999. De plus amples recherches sont nécessaires pour évaluer les hypothèses sur lesquelles sont fondées notre estimation. Les décisions de gestion au sujet de ce stock devraient être prises séparément de celles qui concernent la morue du Nord et refléter l'effectif bas et incertain de la population.

Introduction

Gilbert Bay is located along the southern Labrador coast, 52° 35′ N 56° 00′ W (Fig. 1). Commercial cod fishing took place in Gilbert Bay from the 1970's until 1992, when a fishing moratorium was placed on Atlantic cod in NAFO Divisions 2J + 3KL, the northern cod stock. The northern cod fishing moratorium ended in 1998 and limited commercial fishing resumed. During 1998, commercial fishing along the southern coast of Labrador targeted Gilbert Bay's resident Atlantic cod population because fish were relatively abundant there compared to the very low abundance of offshore migratory cod on traditional fishing grounds outside the bay (Morris 2000). Although it was known that cod in Gilbert Bay were resident, there was little scientific information regarding the population size. Given the data available and size of the area, it was intuitive that the population was small and susceptible to growth and recruitment overfishing. In recognition of the fact that rapid stock depletion was possible, a decision was made to implement a fisheries variation order in fall 1998 to restrict Atlantic cod fishing in most of Gilbert Bay.

Gilbert Bay is now designated as an Area of Interest (AOI) having the potential to become a Marine Protected Area under the *Oceans Act*. If an MPA is established in Gilbert Bay to protect the resident Atlantic cod population, an estimate of the population's size will be needed to establish fishing regulations and subsequently evaluate the effects of those adopted. The scientific research conducted in Gilbert Bay since 1998 has included an Atlantic cod tagging program. During the annual sampling it has been a regular occurrence to recapture tagged fish. This has provided an opportunity to use recapture data to estimate population size. Despite the obvious uncertainties associated with such an estimate we believe that the recapture data and our present knowledge of the biology of Gilbert Bay cod enable us to provide a meaningful population estimate. Our current estimate of the population size includes information based on mark-recapture data, catch per unit effort, and commercial fishing, in Gilbert Bay. Catch per unit effort (CPUE) data, commercial tag return data, and data on the movement of cod are used to expand our population estimate from a portion of the bay (The Shinneys), where research sampling has been concentrated, to the entire bay.

Methods

Mark-recapture

The Gilbert Bay mark-recapture study was begun by J. M. Green (Memorial University) in 1998, and has continued in collaboration with DFO. The initial tagging work was intended to investigate dispersal of fish, and to ensure that individual fish weights, lengths, and reproductive condition were not measured twice unknowingly. Atlantic cod were caught by angling in 2-10 m depths. Healthy Atlantic cod larger than 25 cm were tagged with Floy t-bar anchor tags inserted at the base of the first dorsal fin, and released. Each tag was identified as having a reward value of $10 when returned to DFO; the same type of tag is used by DFO to tag cod throughout the Atlantic Provinces. The

reward is intended to encourage the return of tags recaptured during fishing. Since 1998, 76 Atlantic cod have been recaptured by us during twice yearly tagging trips of approximately 7 days duration, thus the reporting rate for recaptures is 100%. To satisfy several conditions that improve the accuracy of our population estimate only 39 of these recaptures were included in our analysis (see below).

Knowledge regarding the behaviour of Gilbert Bay cod, especially pertaining to their movements, has been incorporated into our population estimate. After completing spawning in late spring and early summer, some cod move towards the mouth of the bay, where they spend part or all of the summer prior to returning to the inner parts of the bay in the fall (Green and Wroblewski 2000; Morris and Green 2002). Therefore, we assume that the use of only tag and recapture data from the spring sampling period ensures that fish: 1) have equal time (1 year) to remix with the population; 2) experience equal natural mortality and tag loss, and 3) have an equal chance of recapture. Consequently, thirty-seven recaptured fish are not included in the population analysis because they do not meet the above criteria. They were either recaptured and or tagged during mid summer. Sonic tracking of 10 fish (Green and Wroblewski 2000), and changes in the length frequency distribution between spring and summer (Morris and Green 2002) indicate that as many as fifty percent of fish move out of, and back to, The Shinneys, and that this movement is size related. We have no data on how many cod from other parts of Gilbert Bay may move into The Shinneys during the summer.

The mark-recapture method used to estimate population size is that described in Ricker (1975):

$$P = CT/R.$$

Where P is the estimated population size, C is the number of fish caught in a sampling period, T is the number of tags available in the population and R is the number of recaptures during the sampling period. Table 1 indicates sampling periods, total captures, number of cod tagged, estimated number of tags available after annual natural mortality and annual tag loss, and recaptures. Independent population estimates are obtained from recaptures sampled during each subsequent spring sampling period. The standard deviation among population estimates provides some indication of the range in our population estimate.

To obtain T for each population estimate, we account for tag loss and natural mortality. The majority of tag loss is assumed to occur during the first year, and is estimated at 0.2 (Brattey and Cadigan 2001; Cadigan and Brattey 1999). Natural mortality is assumed to occur each year, and to be 0.2 per year. It is possible that other tag removals have occurred but were not reported. The consequences of unreported tag removals would be an over estimate of population size. Table 1 indicates that during 1998, 682 fish were tagged. The following year T equals 409 as a result of tag loss (0.2) and natural mortality (0.2). T equals 327 the next year, a further 0.2 reduction in the tags available, but no additional tag loss is assumed. Although other studies estimate a tagging mortality of 0.13 (Brattey and Cadigan 2001) we attribute no mortality to tagging. Gilbert Bay cod were

caught in much shallower water (5-10m) than described by Brattey *et al.* (2002), and they were tagged and released within several minutes of capture.

Sampling CPUE

Sampling CPUE is an indicator of fish abundance. Since the majority of our sampling was in The Shinneys, partly because few fish were available at other locations during the May-June sampling, CPUE data are used to estimate the relative abundance of fish at other locations in Gilbert Bay. All sampling was done with rod and line, so sampling effort is measured as rod hours. Forty rod hours were the minimum sampling effort between our comparison sites, and we assume this effort is sufficient to indicate relative fish abundance. CPUE in The Shinneys and at the head of Gilbert Bay is compared in spring of 2001 and 2002. Abundance between years is not compared because of possible differences in catchability from one year to the next.

Commercial Tag Returns

Commercial tag returns were used as an independent measure to estimate population size, and to provide information about the size distribution of fish caught commercially in Gilbert Bay. The usefulness of commercial tag return data to estimate population size depends on knowing or accurately estimating the reporting rate of recaptured tags. Consequently, we only include commercial tag returns from two commercial fishers who we were confident had reported all tag recaptures. Each of these fishers was interviewed, are known to have fished entire quotas within Gilbert Bay, and returned 25 and 27 tags each. An additional 20 tags were returned by other fishers (total commercial tag returns = 72) but they were used only to describe the length frequency distribution of commercial recaptures and indicate general recapture locations. We assumed that the chance of a recaptured commercially caught cod being reported was not size dependant. For commercial tag returns fish length at tagging was used to predict the length at recapture based on the time at large and growth rate of Atlantic cod in Gilbert Bay given by Morris and Green (2002) ($L_{inf} = 63.2\ (-e^{-0.16(t + 2.9)})$).

We assumed that 50% of tagged cod move from the Shinneys during summer, and were susceptible to commercial capture in the Main Arm of Gilbert Bay. While this assumption is not related to our primary mark-recapture population estimate based on recaptures during scientific sampling, it is used to estimate the number of fish from the Shinneys that were susceptible to commercial fishing in Gilbert Bay. Based on the size of individual quotas for commercial fishers and the tag returns from two fishers, a population estimate was derived. This estimate is compared to our mark-recapture estimate from scientific sampling.

Commercial Catch

Total commercial catch estimates for 1998 and 1999 were determined based on the number of people who fished commercially in Gilbert Bay and their Individual Quota (IQ). Interviews with fishers in the area identified how many people fished commercially in Gilbert Bay each year. Morris et al. (2002) describes the interview process. Fishers reported that cod were abundant in Gilbert Bay, and they caught their allotted IQ. Information from DFO (statistics department) indicated that thirty people from communities near Gilbert Bay (Williams Harbour and Port Hope Simpson) had commercial groundfish licenses in 1998. However, many of these were fishing northern shrimp, and therefore not permitted to fish Atlantic cod in NAFO 2J+3KL. The small number of fishers, and the fact that they know each other's vessels suggests that the data from interviews on numbers of fishers are accurate. Three fishers indicated the number of boats that they were aware of fishing commercially in Gilbert bay, and another six fishers indicated that people were fishing in Gilbert bay but did not comment on the specific number of boats. Interviews suggested that between 14 and 16 boats fished commercially in Gilbert Bay during 1998. Interviews with two commercial fishers in 1999, who caught entire quotas in Gilbert Bay, indicated that only three or four people fished commercially in Gilbert Bay that year. Commercial fishing mortality of Gilbert Bay cod during 1998 and 1999 was estimated from allotted IQ's and number of fishers.

Results

From 1998 to 2002, we angled 4296 cod in Gilbert Bay, tagged 3569, and recaptured 76 tagged fish during sampling; of which 39 are included in the analysis of population size. Population estimates from each recapture period are presented in Table 1, and Figure 3. From the population estimate of each year, numbers of individuals were converted to biomass based on known length frequency distributions, and the populations length-weight relationship ($W = 5.9 \times 10^{-3} L^{3.11}$, $r^2 = 0.98$) given by Morris and Green (2002). We estimate a biomass of 34,000 kg +/- 6000 kg in The Shinneys.

From June 1-6, 2001, based on a minimum of 40 rod hours at each sampling location, the CPUE near the head of Gilbert Bay was 0.5 fish per hour compared to 3.8 fish per hour in The Shinneys. Similarly from June 1-6, 2002 using a minimum of 40 rod hours at each sampling location, the CPUE near the head of Gilbert Bay was 0.6 fish per hour compared to 5.9 fish per hour in The Shinneys. The difference in CPUE was 7.5 times greater in 2001 and 9.4 time greater in 2002 in The Shinneys compared to The Main Arm of Gilbert Bay. The Main Arm of Gilbert Bay (48.7 km^2) is four times as large as The Shinneys (12 km^2) but fish appear to be about 8.5 times more abundant in The Shinneys. Therefore we estimate the number of fish in the Main Arm of Gilbert Bay during spring to be about half that of The Shinneys. Thus, the estimate of individual cod larger than 30 cm in all of Gilbert Bay is between 39000 and 72000 fish, or a biomass between 42 t and 60 t.

Population Estimate from Commercial Tag Returns

The population estimate from commercial tag returns is based on tags returned by two commercial fishers in 1999. Each fisher reported all recaptures, specific fishing locations, total catch, gear type, and fishing dates. One fisher returned 25 tags and the other 27. Fishing locations were near Kelley's Point, Deer Park Point, Coachbox Point, and The Turn (Fig. 1). Their method of fishing was primarily gillnet. The fishing period was primarily during September- November. To estimate the number of fish susceptible to commercial fishing we assume that only one quarter of the tagged fish from The Shinneys move to the outer part of the bay. We base this on information suggesting that fish smaller than 37 cm (approximately half of the fish we tagged) generally stay in The Shinneys, and that half of the larger fish leave The Shinneys following the spawning period. Table 1 indicates that 409 fish tagged in 1998, and 563 fish tagged in 1999 would be available for recapture in 1999. Therefore, the number of tags estimated to be available to the commercial fishery in 1999 is T = (409+563) ÷ 4 = 243; accounting for small fish not moving out of The Shinneys and only half of large fish moving out of The Shinneys. The Individual Quota for 1999 in NAFO 2J was 4082 kg, or approximately 3887 Gilbert Bay cod. Assuming that 3887 fish were caught (C) by each fisher, and that each fisher recaptured a similar number of tags to fill their IQ (N = 25 and 27 respectively), we estimate that 37000 fish were susceptible to commercial fishing in 1999.

Commercial Catch Estimate

During 1998 and 1999 we estimate that 18 tons and 16 tons of Gilbert Bay cod were taken during each year respectively (Table 2). During 1998 it is estimated that between 14 and 16 boats caught entire Individual Quotas (1998 IQ = 1224 kg) from within Gilbert Bay; an estimated 18,360 kg of Gilbert Bay cod. The number of active fishers during 1999 was only three or four. Assuming that four fishers caught entire 1999 IQ's of 4048 kg, an increase from IQ of 1224 kg the previous year, we estimate that 16,192 kg of Gilbert Bay cod was caught in 1999. The total commercial catch over this two-year period is estimated at 34,500 kg or approximately 49000 fish.

From 1998 to 2002, 72 tags were returned to DFO from commercial fishers. Figure 5 shows the length distribution of fish recaptured in the commercial fishery. Figure 4 gives spring length frequency distributions of research samples from 1998 to 2002, which we believe are representative of the entire Gilbert Bay population. The ratio of tags available to tags recaptured per 5 cm length interval indicates that larger tagged fish are more likely to get caught than smaller tagged fish (Fig. 5). This indicates strong gillnet selectivity at >55 cm TL. Fish smaller than 35 cm are less likely to move into the commercial fishing area (Fig. 2) and are also less likely to be caught in the mesh size used in the commercial fishery.

Recreational fishery Catch Estimate 1998

The 1998 recreational fishery for northern cod consisted of two weekend fisheries, during which many people from the Gilbert Bay area caught their recreational fishing quota within Gilbert Bay. During the first weekend fishery in Gilbert Bay the number of boats, number of people, number of fish caught, and fish length and weight were monitored. Each person taking part in the fishery was allowed 10 Atlantic cod per day, with only 50 fish permitted per boat. Part one of the fishery (August 28 and 29) involved 50 boats and 103 people, resulting in the removal of an estimated 1030 fish from the population. We assume that a comparable number of cod were removed during the second part of the 1998 recreational fishery, giving a total catch of 2060 Atlantic cod. The average length of these fish was 50 cm. Converting the number of fish to weight, based on the length-weight relationship of Gilbert Bay cod (Morris and Green 2002), we estimate that the 1998 recreational fishery removed approximately 1000 kg of Atlantic cod from Gilbert Bay. The recreational fishery in Gilbert Bay has not been specifically monitored since 1998, and few tags have been returned to DFO. Tag returns from the recreational fishery are: 1999 (n= 1), 2000 (n=0), 2001(n=0), and 2002 (n=5), but we are aware of a high non-reporting rate.

Discussion

Our estimate of the size of the Atlantic cod population in Gilbert Bay utilized as many sources of information as were available, with sampling recaptures being the most reliable. While the estimate provided is considered to be preliminary, we think it is the right order of magnitude. Additional sampling is clearly needed to verify assumptions and to provide more data, and a longer time series. The various sources of information we used all suggest that the Gilbert Bay cod population is very small in comparison to other cod stocks in the Newfoundland region for which comparable estimates have been made.

The population structure and known removal of a significant portion of the population during commercial fishing since 1998 suggests that the population is not currently at its carrying capacity. In addition, for a period of 15 years before the 1992 commercial fishing moratorium commercial cod fishing occurred in Gilbert Bay. The current length frequency distributions indicate a virtual absence of fish greater than 60 cm and older than 13 years. Based on historical data from other Atlantic cod populations it seems unlikely that the maximum size and age of cod in Gilbert Bay should have these values. Atlantic cod length frequency distributions in NAFO subdivision 2J during 1959, 1960, and1962 had an abundance of cod between 50 and 70 cm, and consisted of many fish older than 13 years (May 1966). It is perhaps unlikely that any virgin stock of Atlantic cod would have so few fish larger than 60 cm and older than 13 years. The age structure of fish in Gilbert Bay today indicates that the population had rebuilt during the northern cod moratorium, but it is unlikely that it had reached its carrying capacity or historical age structure prior to the restart of fishing in 1998.

Population estimate

In most instances, the assumptions made when deriving a population estimate are difficult to verify. However, the fact that we consistently recapture tagged fish during our sampling trips is a strong indication that the Gilbert Bay cod population is indeed small. For most Atlantic cod tagging studies such recaptures during sampling is rare. During Atlantic cod tagging trips conducted over several years in Placentia Bay, DFO researchers recaptured 1 tagged fish per 2500 – 4000 fish caught (John Brattey, Science Branch, Department of Fisheries and Oceans, P O Box 5667, St. John's, NL, Canada, A1C 5X1, personal communication). During our spring sampling in Gilbert Bay we recaptured one fish per fifty sampled that was tagged during a previous spring sampling period. If we include recaptures from summer tagging or summer recaptures, the frequency of recovery is greater, at approximately 1 tag per 35 fish sampled. Other tagging programs in NAFO Divisions 3KL conducted by the Department of Fisheries and Oceans generates 1 recovery per 5000 kg of fish landed (John Brattey, personal communication). While our estimate has considerable uncertainty we believe that our approach has been conservative.

Our population estimate for all of Gilbert Bay is particularly dependent on CPUE data obtained from rather limited sampling in the Main Arm of Gilbert Bay. If we assume that the density of cod were equal throughout Gilbert Bay in the spring, and we used the estimated number of cod in The Shinneys as an indicator of density, we would estimate the population of Gilbert Bay cod to be approximately 150,000 thousand fish, since the main arm of Gilbert Bay is 4 time larger than The Shinneys. However, we think the evidence is compelling that cod are concentrated in the inner portions of Gilbert Bay during the spring spawning period. In addition, it is probable that historical and recent commercial fishing had a larger impact on the density of cod in the Main Arm of Gilbert Bay than The Shinneys. Given our understanding of Gilbert Bay cod behaviour (Green and Wroblewski 2000; Morris and Green 2002), it is likely that Inland Waters Regulations governing The Shinneys and head of Gilbert Bay, provided some refuge from commercial exploitation during 1998 and 1999. Under these regulations, all commercial fishing and the use of nets is prohibited.

Commercial Fishing

During 1998, commercial fishing was permitted throughout Gilbert Bay except in the designated Inland Waters areas (Fig. 1). In 1999, the inner 57.5% of Gilbert Bay was closed to cod fishing. The population estimate based on commercial tag recaptures is useful in that it was derived independently of research sampling recaptures. That two fishers with the same IQ, fishing near the mouth of the bay, each recaptured similar numbers of cod tagged in The Shinneys (25 and 27 tagged fish) suggests that the tagged fish were well mixed with non-tagged fish. Based on the movement and tag returns of fish caught in the commercial fishery we also know that commercial fishing in 1999 targeted large size cod. That a significant proportion of larger cod from throughout Gilbert Bay move to the mouth of the bay in summer means that they are vulnerable to commercial fishing occurring there.

We assume that commercial fishing prior to the cod moratorium of 1992 had already reduced the number of large (>60) and older fish in the population. During the moratorium the population appears to have been recovering, at least until commercial fishing restarted in 1998.

Conclusions

The Gilbert Bay cod population is very small compared to other known stocks in the Newfoundland region. Its small size is likely related to the small geographic range of the population. Excluding Ogac Lake (Patriquin 1967), the Gilbert Bay population is the smallest population of Atlantic cod (both geographically and number of individuals) that we are aware of. The Trinity Bay – Smith Sound aggregation was estimated at 20 000 tons (DFO 2003), and the Placentia Bay population is currently estimated at about 25 000 tons (John Brattey, personal communication). Given the extremely low stock status of Northern cod and the relatively high density of cod in Gilbert Bay, commercial fishing under current management conditions could seriously damage the resident population of Atlantic cod in Gilbert Bay. Because the Gilbert Bay cod population is geographically well defined and restricted to a relatively small area, the possibilities for it to be successfully managed on a local basis with in an MPA are excellent.

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Table 1. Atlantic cod tagging information, recaptures, and population estimates for The Shinney's. Spring sampling was conducted between 15 May and 15 June each year. Tags available to recapture (T) assumes 0.2 tag loss during first year and 0 afterwards, and 0.2 natural mortality each year. Population estimates, P, are based on C (number of fish caught during each spring sampling period), T, and R (recaptures from each spring tagging period). P = CT/R.

	1998	1999	2000	2001	2002
			Spring tagging information		
Caught	748	594	458	344	759
Tagged	682	563	430	278	650
			Number of fish caught in spring (C), tags available (T), recaptures (R), and population estimates (P).		
	C	594	458	344	759
	T	409	327	262	210
	R	9	6	0	3
	P	26994	24961	-	53130
		C	458	344	759
		T	338	270	216
		R	3	4	4
		P	51601	23220	40986
			C	344	759
			T	258	206
			R	2	4
			P	44376	39089
				C	759
				T	167
				R	4
				P	31688
Ratio of recaptures to fish caught		1:66	1:51	1:57	1:47

Table 2. Estimated number of individuals caught during the 1998 and 1999 commercial fishery in Gilbert Bay. The Expected mean weight of individual fish per 5 cm length interval for Gilbert bay cod is indicated. The percentage of fish per 5 cm interval was obtained from the lengths of tagged fish returned by commercial fishers.

			1998 estimate of total catch		1999 estimate of total catch	
Length interval (cm)	Expected individual mean weight (kg)	Percent commercial recaptures	Biomass caught (kg)	Estimated number of individuals	Biomass caught (kg)	Estimated number of individuals
30-35	0.297	7	1285	4327	1133	3816
36-40	0.464	21	3856	8309	3400	7328
41-45	0.684	23	4223	6174	3724	5445
46-50	0.967	20	3672	3797	3238	3349
51-55	1.320	13	2387	1808	2105	1595
56-60	1.750	10	1836	1049	1619	925
61-70	2.270	4	734	324	648	285
66-70	2.884	2	367	127	324	112
Total biomass and expected number of individuals			18360	25916	16192	22856

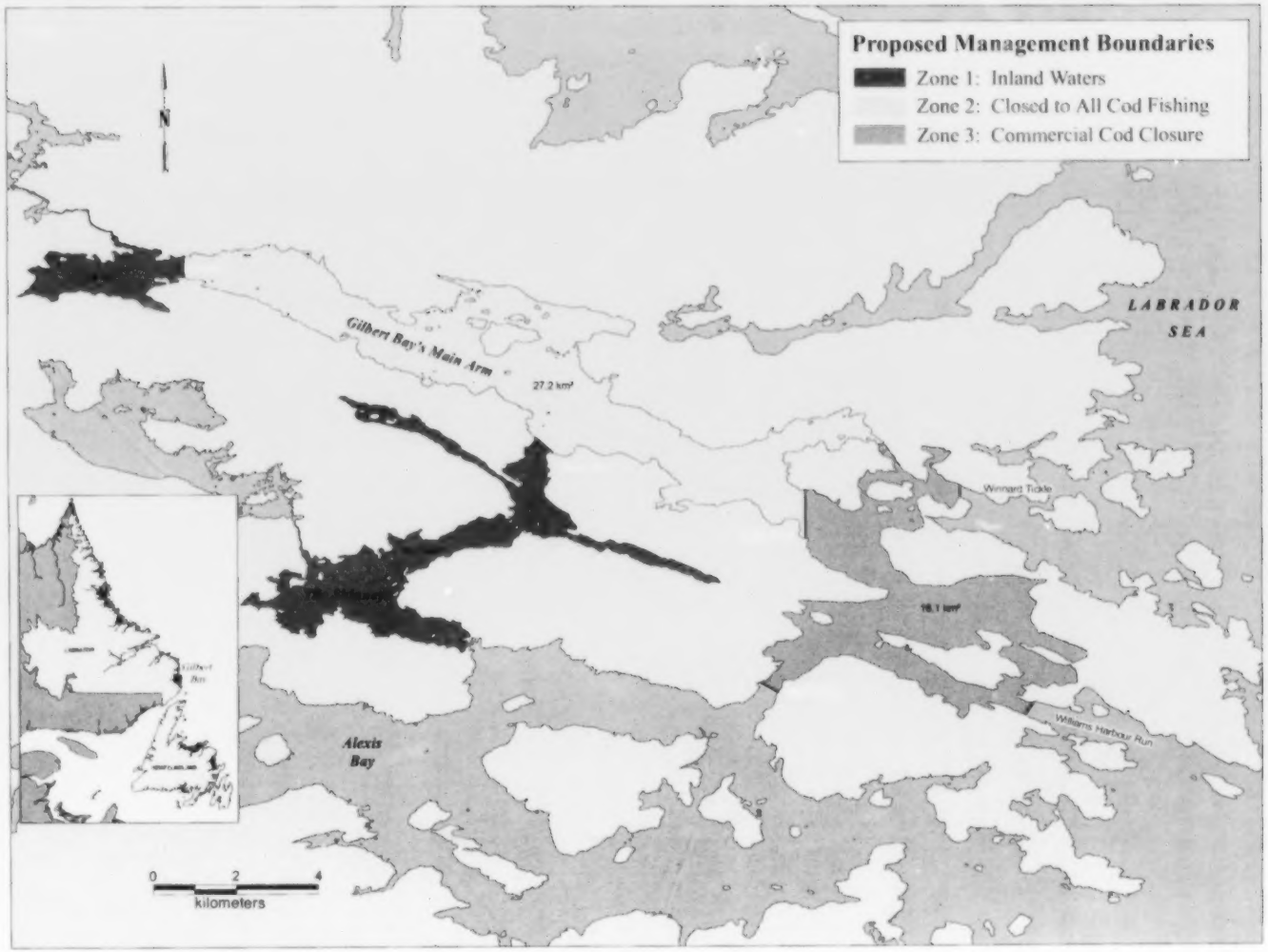

Figure 1. Map of Gilbert Bay, local place names and proposed management boundaries.

Figure 1. Map of Gulbert Bay, local place names and proposed management boundaries.

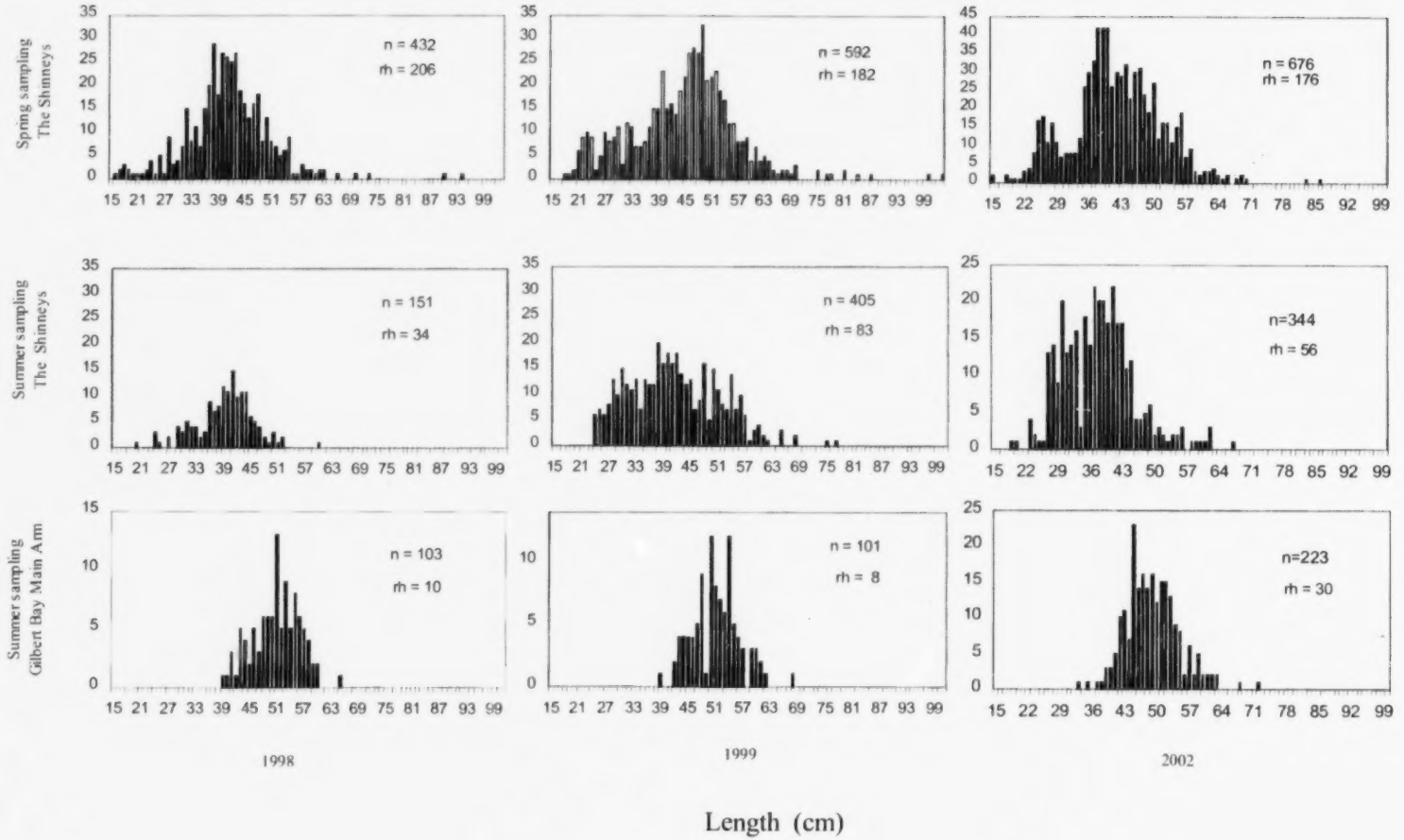

Figure 2. Length frequency distribution of Gilbert Bay cod sampled in The Shinneys during spring (15 May 15 June) and sampled in The Shinneys and Main Arm of Gilbert Bay during summer (28 July 15 August). Samples collected in the Main Arm of Gilbert Bay during spring are not included because of their small numbers. The number of fish sampled (n) and number of hours (rh) used to sample fish are indicated.

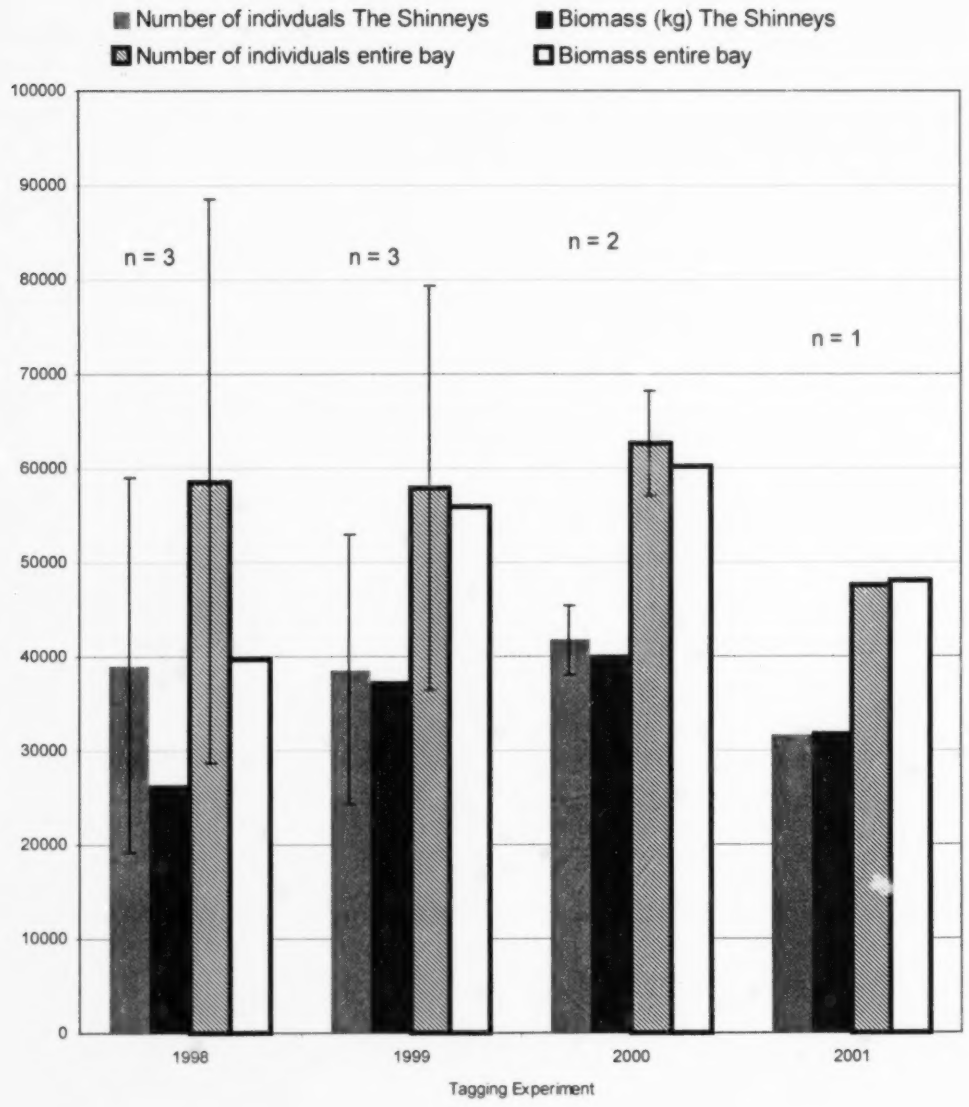

Figure 3. Population estimates based on recaptures from each spring tagging experiment. Standard deviations of the population estimate for each tagging experiment are based on independent population estimates from recaptures caught during each spring sampling period after the initial spring tagging period. This is an indication of the range surrounding our estimates, albeit a very small number of estimates as indicated by n values. Biomass estimates, based on population estimates, weight at length, and length frequency distributions, are also indicated.

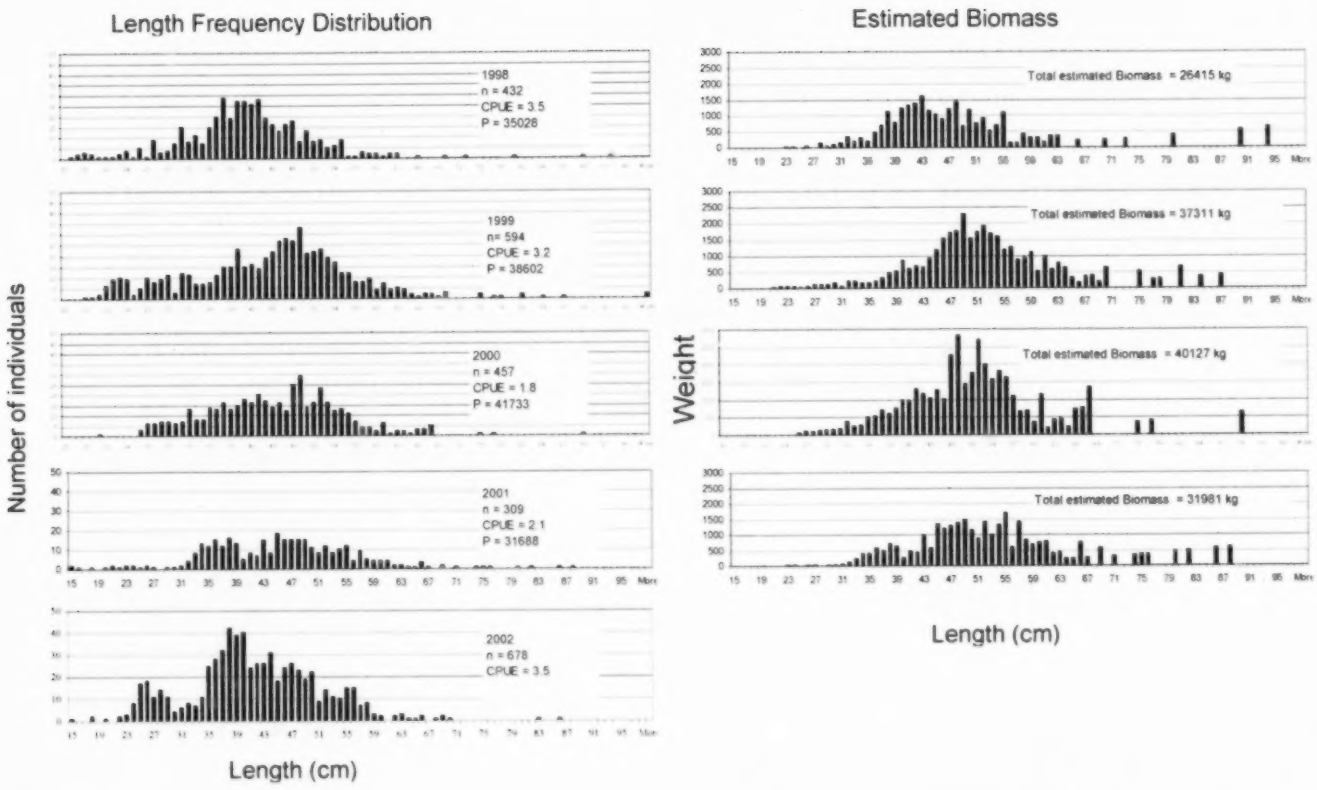

Figure 4. Length frequency and biomass distributions of cod sampled in The Shinneys during spring. We assume that the sampled population is representative of the entire population. Biomass estimates are based on the estimated population size from tag recaptures, predicted weight at length from the equation W = 5.9x10-3 L3.11 given by Morris and Green (2002), and proportion of fish in 1 cm length intervals.

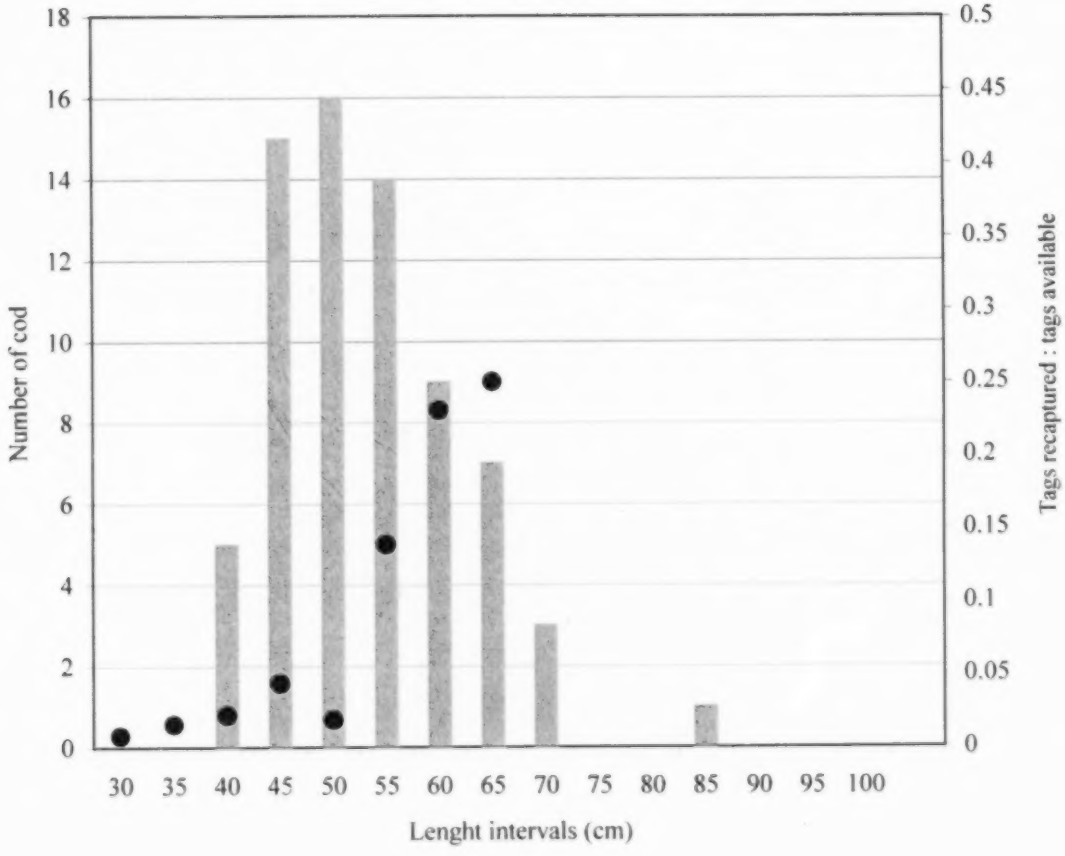

Figure 5. Length distribution of 72 externally tagged cod recaptured during commercial fishing in Gilbert Bay. Length at recapture is predicted from the time at large between capture and recapture and growth rate of Gilbert Bay cod described by Morris and Green (2000). The ratio of tagged fish recaptured and reported to tagged fish available (assuming 50% of tagged fish move from The Shinneys to commercial fishing areas) per 5 cm interval is indicated on secondary y-axis.